AD-A166 466 FATIGUE BEHAVIOR OF LONG AND SHORT CRACKS IN WROUGHT AND POWDER ALUMINUM. (U) CALIFORNIA UNIV BERKELEY DEPT OF MATERIALS SCIENCE AND ENGINE. R O RITCHIE

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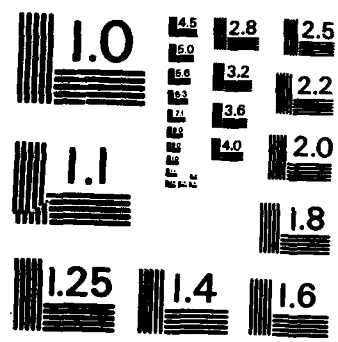

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The fatigue behavior of short cracks, which are small compared to the scale of the microstructure, small compared to the scale of local plasticity or simply physically small (i.e., $\sim$1 mm), must be considered as one of the major factors limiting the application of defect-tolerant fatigue design for airframe and engine components. Accordingly, the current program is aimed at identifying factors which govern the growth of such short cracks (in contrast to long cracks) in a series of commercial aluminum alloys, with specific reference to behavior at near-threshold levels (below $\sim 10^{-6}$ mm/cycle). ~~In this Research Progress and Forecast Report,~~ a summary of the research performed during the past six months is described, together with a review of future work.

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RESEARCH PROGRESS AND FORECAST REPORT

Fatigue Behavior of Long and Short Cracks in Aluminum Alloys
R. O. Ritchie, University of California, Berkeley
Grant No. AFOSR-82-0181

It is now known that fatigue crack propagation in precipitation-hardened aluminum alloys is influenced significantly by mechanisms of crack tip shielding, notably by crack deflection and roughness-induced crack closure. Such mechanisms provide an impedence to crack advance by locally reducing, i.e., shielding, the "crack driving force," primarily through the generation of a meandering crack path morphology. However, since such mechanisms act principally on the crack wake, they are expected to be minimized where cracks are small or emanating from a notch or, in the case of closure induced by rough fracture surfaces, where compressive cycles are applied. Therefore, in alloy systems where significant crack tip shielding can be developed, it is anticipated that the microstructural factors favoring resistance to long crack growth may be distinctly different from those factors favoring resistance to crack initiation and short crack growth. Accordingly, studies over the past year have been directed to further examining the influence of crack tip shielding to explain the anomalous behavior of small flaws and the growth of arrested threshold cracks by single compression cycles. Specifically, work has been focussed on i) definition of the role of microstructure in influencing fatigue crack growth and closure behavior for long and physically-short cracks in 2124 Al-Cu alloy, ii) further examination of effects of variable amplitude loading including compression cycles on arrested near-threshold cracks in 7150 Al-Mg-Cu alloy, and iii) a new study to examine long and physically-short crack behavior in a 2090 Al-Cu-Li alloy, known for its tortuous crack paths.

Based on experiments in 2124, it has been confirmed that the fatigue threshold stress intensity range, ΔK_{TH}, for the dormancy of long ($\gtrsim$ 20 mm) crack is intimately associated with the development of roughness-induced crack closure. Similar to studies in 7150 alloy, it has been found that thresholds are higher in underaged, compared to overaged, structures, where the coherent particle hardening promotes a more faceted crack path to enhance both crack deflection and closure. Moreover, by machining away material from the wake of arrested threshold cracks to reduce such closure from asperity contact, crack propagation at ΔK_{TH} can be readily obtained, thereby providing a simulation of short crack growth from a notch. Short cracks are thus expected to propagate at stress intensities below the threshold. Our most recent studies on physically-short cracks in underaged microstructures show this to be the case. With flaws as small as 0.05 to 0.22 mm (which are still large compared to plastic zone sizes), sub-threshold crack extension rates have been monitored at progressively decreasing growth rates, consistent with a measured increase in crack closure approaching 90% shielding of the applied stress intensity range. Current studies are focussed on the magnitude of these effects in overaged microstructures.

Similar studies have been performed on arrested threshold cracks in 7150 alloy where compression overloads have been applied. As documented last year for low load ratios (R), such compressive cycles lead to a reduction in closure, primarily through the compaction of fracture surface asperities, resulting in the re-initiation of crack growth at ΔK_{TH}. Subsequent growth rates, however, are progressively reduced as closure is re-generated by crack extension. More recent experiments on overaged microstructures have probed the effects of tensile unloading cycles and of compressive overload cycles at high load ratios. In marked contrast to behavior at R, the latter two variable amplitude loading sequences do not result in any re-initiation of crack extension at threshold stress intensities. Careful measurement of the closure stress intensity, K_{cl}, using back-face strain techniques, indicated that K_{cl} remained less than K_{min} throughout the loading excursions such that the effective stress intensity at the crack tip was unchanged. This is to be contrasted with low R behavior where the compression cycle lowers K_{cl} such that the effective ΔK is increased.

As noted previously, these studies highlight the inherent fallacy of utilizing fatigue threshold values to predict the dormancy of either long or short cracks in damage-tolerant design calculations for constant or variable amplitude cycling conditions. To accentuate this point, studies have been initiated on an alloy which develops extreme shielding through crack path deviation and microcracking, namely the aluminum-lithium alloy 2090. This material, which is currently arousing great commercial interest, shows far superior long crack growth resistance to conventional airframe aluminum alloys, because of this shielding. The short crack and compression cycling behavior, however, may be decidedly less attractive. Preliminary results to date appear to confirm this as arrested threshold cracks have been observed to commence growing after only 200% compression overloads, whereas no growth is seen in 7150 until 500% overloads are applied.

There have been no departures or deviations from the planned research objectives, as outlined in the last Annual Report, dated May 1985. Current studies are being directed to i) a continuation of the sub-threshold short crack studies in overaged 2124, to compare with underaged microstructures, ii) experiments with center-cracked tension (CCT) samples to compare with compact tension (Prandtl field) geometries, and iii) definition of the behavior of short cracks and cracks subjected to compression overloads in aluminum-lithium alloys. It is anticipated that this work will provide a microstructural basis for understanding differences in long and physically-short crack growth behavior and to provide useful guidelines for the design of alloys with increased resistance to fatigue.

The personnel and publications relating from this work are listed below:

PERSONNEL

Prof. R. O. Ritchie, Principal Investigator
Dr. W. Yu, Research Engineer
J. Miwa, Graduate Student Research Assistant (from 9/85)
H. Hayashigatani, Undergraduate Engineering Aide

PUBLICATIONS

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